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Micheal D. K. Owen
Iowa State University, mdowen@iastate.edu

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Weed management update for 2014

Micheal D.K. Owen, University professor, associate chair and Extension weed specialist, Agronomy, Iowa State University

Introduction

Weed management in 2014 will continue to be more challenging regardless of the weather. Factors such as prevented planting, poor weed control in 2013, increasing populations of weeds with evolved herbicide resistances and recently, the discovery of Palmer amaranth in Iowa will make weed control decisions interesting. However, other factors such as grower and dealer attitudes, promotional incentives, desire for simple and convenient tactics and perceived costs of more diverse alternative approaches to weed management programs are still primary considerations impacting weed control. Increasing the diversity of weed management tactics will improve the consistency of weed control, mitigate herbicide-resistant weeds and increase profitability. However, these tactics will require more planning, time, and possibly higher initial costs; to effectively diversify weed management requires that fields be considered individually and possibly unique strategies for each field. All possible "tools" should be considered and as many as possible included. There is a long history demonstrating that simple and convenient approaches to pest management, and in particular weed management will inevitably fail biologically and economically. The objectives of this paper are to provide an update of changes in the industry that may impact weed management decisions for 2014, review the state of herbicide resistant weeds in Iowa, provide some information about alternative weed management tactics and list some perspectives about weed management decisions.

Selected industry updates

Industry representatives were asked to provide information about their proprietary products, programs and new developments that would potentially impact weed management in 2014. Based on the responses, it is clear that the trend of no new herbicide mechanisms of action continues. Furthermore, while there are a number of new herbicide premixtures now available, these represent combinations of older products. One thing that is consistent across the industry is to highlight using proprietary products to address the issues of evolved resistance to herbicides. Development of new genetically-engineered herbicide-resistant crop cultivars continues although the target herbicides that have been available for many years and to which waterhemp has already evolved resistance. Not all companies are represented in this update which reflects whether or not they accepted the opportunity to submit information. Inclusion of any product in this update does not imply endorsement nor does exclusion imply that the product is not recommended.

BASF has reported that a number of products are no longer available. Specifically, G-Max Lite and Guardsman Max herbicide are no longer formulated. Clearfield corn systems are essentially dead and Distinct is no longer labeled on corn. Armezon is labeled for application up to 45 days prior to harvest however cannot be applied to corn that is beyond the V8 growth stage. Outlook herbicide is now labeled to be applied postemergence to soybeans from emergence (cracking) to the fifth trifoliate stage of development however weeds that have emerged will not be controlled by the Outlook. This strategy will provide extended residual control of waterhemp, Palmer amaranth and grasses. If a preemergence application of Outlook is followed by a postemergence application, at least 14 days between applications should occur and the seasonal total of 24 ounces of Outlook should not be exceeded. The first application should be 8 to 16 ounces and 8 to 16 ounces (depending on the first application) for the second application. Zidua is now labeled for soybeans and can be applied preplant surface, preplant incorporated, preemergence and early postemergence (1st to the 3rd trifoliate). Sharpen can be used as a harvest aid/desiccant in soybeans.

Bayer CropScience has continued with an emphasis on better management of weeds and specifically are targeting herbicide-resistant weeds. Liberty herbicide in conjunction with Liberty Link corn and soybean represents a good tactic to help manage weeds, particularly those that have evolved resistance to glyphosate. Bayer CropScience recommends that residual herbicides be used along with the Liberty and highlights the need for timely application on smaller weeds. In the Bayer CropScience "Respect the Rotation", the need for alternative tactics, integrated weed management, and timeliness is stressed. Some growers, however, are looking to continue the type of management programs that were used in glyphosate-based systems. This is particularly a concern in the Mississippi Delta where a relatively high percentage of growers indicate plans to switch to Liberty Link crop cultivars and only apply Liberty as the sole weed management approach. This approach will result in weeds with evolved resistance to Liberty in a few years.

Cheminova is marketing Crusher which is a premixture of rimsulfuron and thifensulfuron-methyl, both Group 2 herbicides. Fall, preplant and preemergence applications are registered for corn while fall and preplant (30 days or more before planting) are registered for soybeans.

Dow AgroSciences are continuing to develop the 2,4-D resistant corn and soybean cultivars however the anticipated deregulation has been delayed due to a required Environmental Impact Statement. Also a number of new acetochlor products with and without atrazine are now available. Surpass NXT is a 7 pound per gallon acetochlor registered for all types of corn including seed corn, popcorn and sweetcorn. KeyStone NXT and KeyStone LA NXT are also registered for all types of corn with the amount of acetochlor and atrazine included in the premixture changing depending on the specific product. FulTime NXT is an encapsulated formulation of acectochlor and atrazine now available for application to all types of corn.

DuPont Crop Protection is anticipating the registration of Trivence herbicide for use in soybeans. Trivence is formulated as a water dispersible granule and contains chlorimuron ethyl, flumioxazin and metribuzin and may be applied preplant or preemergence up to three days after planting. Panoflex and Alluvex are now registered. Panoflex contains tribenuron methyl and thifensulfuron methyl, both Group 2 herbicides, is formulated as a water dispersible granule, and can be applied postharvest, fallow or preplant burndown prior to corn or soybeans. Alluvex is a water dispersible formulation of rimsulfuron and thifensulfuron-methyl that can be applied preplant, preemergence or a burndown treatment in field corn. DuPont also will be introducing a number of formulation and name changes for several existing products. Canopy will now formulated as a homogeneous blend metribuzin and chlorimuron ethyl water dispersible granules and renamed Canopy NXT. Similarly, Breakfree herbicides will be renamed Breakfree NXT herbicides. DuPont is also stressing at plant, burndown and fall applications of their proprietary herbicides such as Basis Blend, Envive, Enlite, and Instigate. Refer to the labels for specific application details.

FMC has a new premixture called Authority Maxx which has a 16:1 ratio of sulfentrazone and chlorimuron ethyl compared to an 8:1 ratio in Authority XL. Solstice which is a premixture of Cadet and mesotrione will be registered for corn. Marvel is a premixture of fluthiacet methyl and fomesafen registered for preplant burndown and postemergence applications in soybean. Anthem which is a premixture of fluthiacet and pyroxasulfone will be labeled for soybeans and supplements the existing corn registration.

Makhteshim Agan of North America (MANA) will be marketing a number of herbicides in 2014. Pummel is a premixture of metolachlor and imazethapyr registered for soybeans. Rumble is a formulation of fomesafen registered for postemergence application to weeds in soybeans. Torment is a combination of fomesafen and imazethapyr that can be applied preplant, preemergence and postemergence in soybeans. Tailwind is a combination of metolachlor and metribuzin that is registered for preplant incorporated and preemergence application in soybean.

Syngenta is marketing Callisto GT for postemergence applications in glyphosate-tolerant corn. This product contains mesotrione and glyphosate. Lexar EZ and Lumax EZ are new premixtures of mesotrione, metolachlor atrazine and benoxacor (a safener) registered for corn. These two premixtures have different ratios of the three herbicides and are registered for all types of corn and grain sorghum. Label tank mixing guidelines for Gramoxone SL 2.0 have been modified; specifically, the order that the non-ionic surfactant is added has changed to be added prior to any herbicides. The label also now describes the addition of crop oil concentrates or methylated seed oils. Sequence (metolachlor plus glyphosate) is now registered in Iowa for use in corn.

Perceived and actual state of herbicide resistance in Iowa

Based on a limited-scope survey that was conducted during a 2012 meeting series on the management of herbicide resistance, it is clear that generally, Iowa growers and industry representatives do not feel that issues with herbicide-resistant weeds are particularly serious (Table 1). When you consider that only 11% of the grower respondents reported that Group 2 herbicide resistance is widespread and the most consistent response from growers with regard to herbicide resistance was “unsure” suggests that despite all of the efforts to provide information about herbicide-resistant weeds, growers are still are unclear about the seriousness of the problem or do not believe that herbicide-resistant weeds will impact their crop production systems. The one exception to this prevailing perception was for

Group 9 (glyphosate) resistance; given the avalanche of information of all public media forms for the last few years, it appears that this message has resonated with growers and the industry. Contrasting these perceptions of how prevalent herbicide resistance is in Iowa with estimates of resistance based on evaluations of weed populations in 2011, it is striking to see the differences between grower and industry perceptions and the reality based on randomly selected fields and greenhouse herbicide resistance evaluations.

Estimates of the prevalence of herbicide resistance to full rates of herbicides applied postemergence to waterhemp populations collected from Iowa soybean fields in 2011 suggest that Group 2 resistance is present on 62% to 77% of Iowa soybean fields, Group 5 resistance on 44% to 51%, Group 9 resistance on 42% to 48%, Group 14 resistance on 10% to 12% and Group 27 resistance on 24% to 27% of the Iowa soybean fields. Importantly, multiple herbicide resistance was found in 88% of the waterhemp populations evaluated and this value represents an estimated 56% to 65% of the Iowa soybean fields.

Table 1. Perceptions about the prevalence of herbicide resistance.
Funded by the United Soybean Board. (www.weeds.iastate.edu/mgmt./2013/forgetpast.pdf)

	Herbicide group				
	HG 2	**HG 5**	**HG 9**	**HG 14**	**HG 27**
	---------- *% farmer (% industry) survey responses* ----------				
Widespread	11 (38)	11 (9)	27 (44)	2 (2)	2 (2)
Isolated	19 (42)	18 (60)	40 (45)	11 (35)	13 (20)
Not present	26 (7)	27 (11)	11 (4)	38 (33)	38 (52)
Unsure	44 (13)	44 (20)	22 (6)	49 (30)	47 (26)

A more recent assessment of grower experiences and perceptions related to herbicide-resistant weeds was made available in October 2013 (Arbuckle Jr. and Lasley, 2013). The poll reports on more than 1200 response which represented a 56% return rate of the questionnaires. The survey included an extensive series of questions concerning whether or not grower had problems with weeds resistant to Group 2, 5, 9, 14 and 27 herbicides.

Interestingly, the responses are very similar to the data reported in Table 1, although the questions were posed somewhat differently. The poll also reported on management practices used for herbicide-resistant weeds; 52% of the respondents reported changing the weed management program in response to the presence of herbicide-resistant weeds and 81% made more than one herbicide application to a single crop in a single season. Respondents indicated that they developed their own herbicide programs 45% of the time but 65% hired a custom applicator to make the herbicide application (Arbuckle Jr. and Lasley, 2013). Only 19% of the respondents reported that no formal scouting was employed to determine the need for a postemergence herbicide application.

Responses to questions about other strategies for the management of herbicide-resistant weeds were somewhat surprising. Multiple modes of herbicide action (MOA) used each season were reported by 71% of the respondents and 60% of the respondents reported using multiple MOAs in each herbicide application. Generally these practices were reported in a favorable light (Arbuckle Jr. and Lasley, 2013).

A market survey information conducted by Monsanto provides evidence that herbicide usage has changed somewhat in the last few years although these changes do not appear to be sufficient to stop the flood of evolved resistance to glyphosate (Figure 1). Consider that herbicides other than glyphosate are used on only 78% of the corn grown in the Midwest and less than 50% of the soybeans. This suggests that there are too many acres of corn and soybeans that rely only on glyphosate for weed management despite all of the information available about the problems of evolved resistance to glyphosate in important weed species.

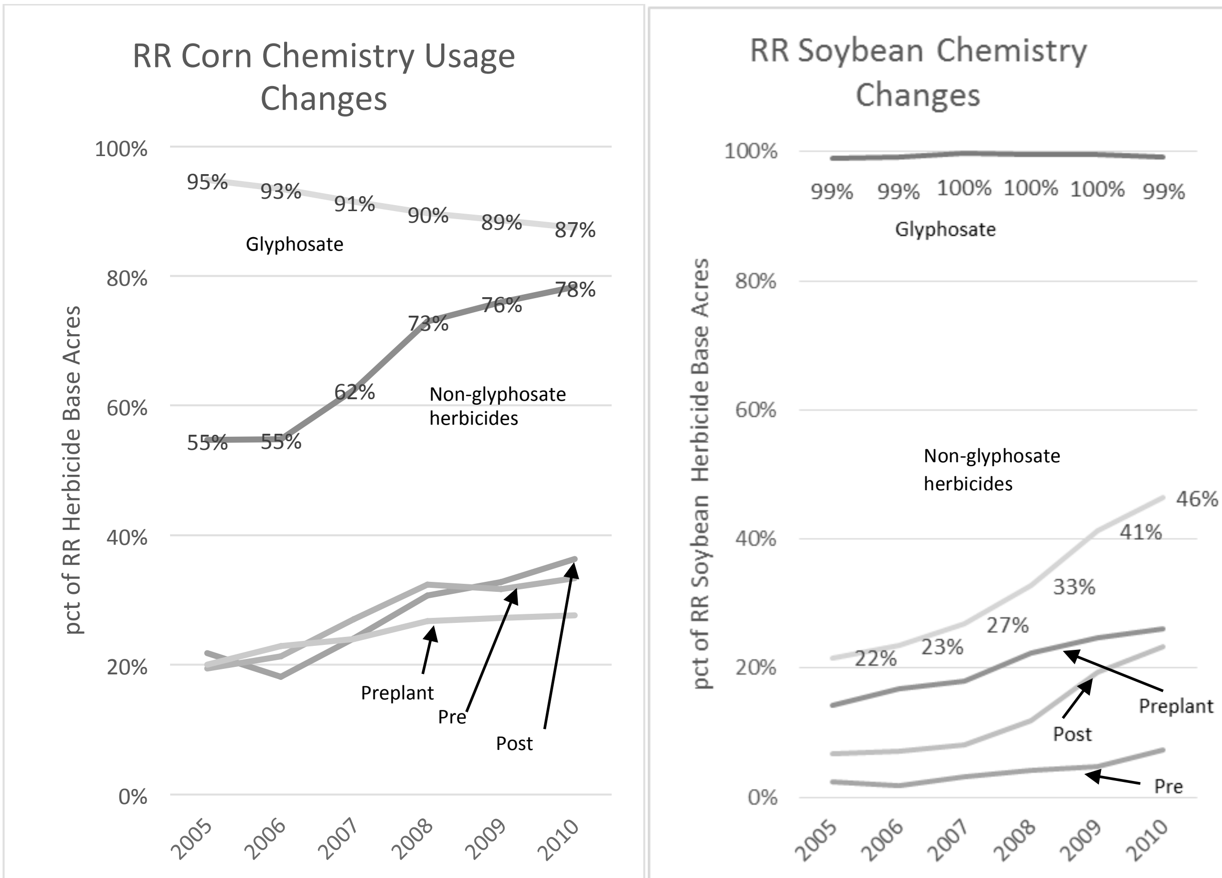

Figure 1. Use of glyphosate and non-glyphosate herbicides in glyphosate-resistant corn and soybean. (Adapted from (Soteres, 2012)).

Alternative tactics for herbicide-resistant and herbicide-sensitive weed management

There has been considerable discussion about developing more diverse weed management programs recently and most of the discussion has focused on improving control of weeds with evolved resistance(s) to herbicides (Table 2). However, the diversity that most growers are currently willing to consider reflects primarily on changing, adjusting or adding herbicides. There has been considerable traction to the rotation of herbicides and including multiple herbicide mechanisms of action (MOA), however there is not, in the opinion of the author, a good understanding of how to implement these tactics effectively (Arbuckle Jr. and Lasley, 2013; Norsworthy et al., 2012). In part, this lack of understanding is attributable to socio-economic issues (e.g., time management and perceived costs) but also because of poor or unclear communication by the industry and compounded by a lack of understanding on the part of growers (e.g., recognizing the MOA of herbicide pre-mixtures, identifying herbicide resistance(s) in specific fields) (Owen, 2012). Clearly, the discussion about alternative weed management should go beyond solely focusing on herbicides. Consider that there are no truly new or novel tactics to manage weeds, just recycled or reinvented ideas. Integrated weed management has not changed in principle but has been redefined and revisited as deemed necessary to meet current crop production systems (Baldwin and Santelmann, 1980; Blackman, 1950; Green and Owen, 2011). An incomplete description of alternative weed management tactics follows; recognize the greater the diversity of tactics, the more successful the overall weed management program will be. Often, the combination of tactics will supplement each other resulting in considerably better management of weeds (De Bruin et al., 2005; DeVore et al., 2012; DeVore et al., 2013; Katsvairo and Cox, 2000b; Krutz et al., 2009).

Crop rotation

Historically, diverse crop rotations have demonstrated consistent positive impacts on weeds; weed population densities and biomass production are markedly reduced by crop rotations which provide diversity over time (Liebman and Dyck, 1993)(Table 2). Crop rotations can be supplemented by intercropping tactics which provides increased diversity spatially. Crop rotation impact weeds by creating a different environment by changing resource competition, soil disturbance and other aspect of the crop system resulting in an unstable situation for specific weeds that have proliferated in a system lacking crop rotation. However, the diversity of the crop rotation should consider the herbicide options available for all rotational crops. Where herbicides are not used on specific crops in a diverse crop rotation system, the reduction of the weed seedbank may be lessened (Gulden et al., 2011). However for more complex the crop rotation schemes, one crop without an herbicide treatment may not negatively impact the overall reduced weed seedbank. Tillage used in a diverse crop rotation program impacts the effectiveness on weed management as well as the potential crop yield and overall economics of the system (Katsvairo and Cox, 2000a; Katsvairo and Cox, 2000b). Crop rotation as an herbicide-resistant weed management practice was reported to be somewhat effective, effective or very effective by 97% of the respondents to the 2013 Iowa Farm and Rural Life Poll (Arbuckle Jr. and Lasley, 2013).

Cover crops

Cover crops provide pecuniary and non-pecuniary (on farm and off farm) benefits when they are included as a component of a crop production system (Snapp et al., 2005). The benefits provided by cover crops include, but are not limited to pest suppression, reduced soil erosion, improved water quality and better nutrient cycling. The costs of cover crops, reflecting both economic as well as time utilization cost, are important considerations when deciding the utility of cover crops (Snapp et al., 2005). There has been considerable interest in using cover crops as a component of a diversified weed management program to help control herbicide-resistant weeds, particularly in reduced tillage systems (Price and Norsworthy, 2013). However, results for weed efficacy are mixed and depend a lot on weed population density, cover crop species and other environmental and edaphic factors (De Bruin et al., 2005; Hayden et al., 2012; Price and Norsworthy, 2013). Vetch (Vicia villosa) and rye (Secale cereal) suppressed winter annuals up to 98% in reduced tillage systems on loamy sand soils in Michigan (Hayden et al., 2012). Rye in experiments with high and low weed population densities demonstrated variable results; where low weed population densities existed, the properly managed rye cover crop had soybean yields equivalent to treatments with a two-pass herbicides. However when weed population densities were high, the rye cover crop did not provide adequate weed suppression making this system less profitable when compared to a conventional system of weed management (De Bruin et al., 2005). The allelotoxin aspect of some cover crops needs further study but to date seems ephemeral at best (Price and Norsworthy, 2013). Cover crops were used by 16% of the Iowa growers to respond to a recent poll and they indicated that the practice was somewhat effective by 23% of the growers, effective by 29% and very effective by 11% of the growers who responded to this question (Arbuckle Jr. and Lasley, 2013).

Fall herbicide applications

Increasing problems with winter annual weeds (e.g., horseweed/marestail, henbit, field pennycress) and simple perennials (e.g., dandelion) which are well-adapted to the conservation tillage systems that dominate Iowa crop production has resulted in growers considering fall herbicide applications. Fall herbicide applications are also seen as a tactic that can improve time management in the spring when the time available for crop production can be limited, depending on the weather (Table 2). The number of companies who are promoting proprietary products for fall applications are increasing and the claims made to support these products are typically quite attractive with regard to the described benefits.

There are several keys to improving the success of a fall herbicide application but the most important factor is to establish reasonable and objective expectations. Some of the products are promoted to provide weed control well into the following spring; while this can occur, the certainty of spring residual control from a fall-applied herbicide is highly dependent on the spring weather. Thus, it is prudent to not expect much residual control in the spring following a fall herbicide application and plan accordingly for the spring weed management program.

Another important consideration is field history and knowledge about the weed infestations. In many instances, broadleaf weeds are the primary concern and thus 2,4-D may be the best herbicide to consider. A number of Group 2 herbicides are currently registered for fall applications; consider that Group 2 herbicide resistance is common in horseweed/marestail. Some Group 14 herbicides that provide contact activity on existing broadleaf weeds at the time of fall application and potentially may provide some residual control in the spring. Consider however that using these products may limit options in the spring.

Set objective expectations for fall herbicide applications, identify the target weeds, and determine how the fall applied herbicide fit into the weed management plans in the spring.

Tillage, mechanical, flaming and other novel tactics

The primary purpose of tillage, whether primary (e.g., moldboard plow) or secondary (e.g., cultivation, rotary hoe) in agriculture is to provide weed management (Table 2). The Iowa Farm and Rural Life Poll included questions about tillage, hand-weeding and mechanical tactics to manage herbicide-resistant weeds (Arbuckle Jr. and Lasley, 2013). Tillage as a practice to help manage herbicide-resistant weeds was reported by 74% of growers who responded to the questionnaire while only 25% reported to having used mechanical control tactics (Arbuckle Jr. and Lasley, 2013). However, these practices were generally reported to be effective for helping to manage herbicide-resistant weeds.

Multiple rotary hoeing was reported to be effective for weed management as was combining rotary hoe with flame cultivation in organic vegetable production (Taylor et al., 2012). Rotary hoes designed to handle high crop residues did not disturb the surface residue cover but were inconsistent with regard to weed control (Bates et al., 2012). High residue inter-row cultivators were reported to be very effective but did reduce surface residue cover. Using multiple mechanical tactics as well as herbicides provided a more complex weed management system but provided similar high yields and economic returns as the herbicide-intensive crop production systems (Bates et al., 2012).

Flaming has been demonstrated to be effective for a number of crops and a number of weed species. However, not unlike mechanical cultivation, timeliness requirements, actual time expenditure and energy consumption are critical considerations (Knezevic et al., 2009a; Ulloa et al., 2012; Ulloa et al., 2011a; Ulloa et al., 2010a; Ulloa et al., 2011b; Ulloa et al., 2010b; Ulloa et al., 2010c). Furthermore, the potential for crop injury from flaming is higher than with mechanical cultivation (Knezevic et al., 2009b).

Table 2. Assessment of current and alternative tactics to help manage weeds (Adapted from (Owen, 2001))

Tactic	Benefits	Risks	Relative effectiveness	Adoption rate
Herbicide MOA rotation	Reduced selection pressure, control of herbicide resistant weeds, greater diversity	Lack of new and available MOAs, phytotoxicity, limited weed spectrum of alternatives	Fair to excellent	High
Herbicide mixtures	Reduced selection pressure, improved control, broader weed spectrum, greater diversity	Poor activity on HR weed species, increased cost, potential phytotoxicity, use of reduced herbicide rates	Fair to excellent	High
Variable application rate and timing	Better control of target weeds, more efficient use of herbicides, fall applications for winter annuals	Reduced residual activity, poor application timing, more applications, selection for non-target site resistance	Fair	Medium
Adjusted herbicide rates	Better control of target species, longer residual activity	Increased target-site selection pressure with higher rates, increased non-target site selection with reduced rates	Excellent (high rates), Poor (reduced rates)	High
Precision application	Decreased herbicide use, reduced selection pressure	Increased application cost, weed maps unavailable, poor understanding of weed seedbank dynamics, variable control	Fair	Low
Primary tillage	Decreased selection pressure, greater diversity, consistent efficacy, depletion of weed seedbank	Increased time required, increased soil erosion, increased costs, more fuel used, supplemental tactics required	Good to excellent	Medium

Tactic	Benefits	Risks	Relative effectiveness	Adoption rate
Mechanical tactics	Decreased selection pressure, consistent efficacy, relatively inexpensive, greater diversity	Increased time required, possible increased soil erosion, increased costs, more fuel used, possible crop injury	Fair to good	Low
Crop selection/ rotation	Improved diversity, allow different herbicide options, reduced selection pressure	Economic risks of alternative rotation crops, rotation crops too similar to increase diversity, inconsistent impact on HR weeds, lack of research base	Fair to good	Low to high
Adjusted planting time	Improved efficacy on target weeds, reduced selection pressure	Requires alternative strategies, potential for yield loss, need for increased rotation diversity, useful for specific crops	Fair to excellent	Low
Adjusted seeding rate	Improved crop competitive ability, reduced selection pressure	Increased seed costs, potentially increased risk from other pests, increased intraspecific competition, reduced yields	Fair	Low to medium
Planting configuration	Improved crop competitive ability, reduced selection pressure	Limits mechanical tactics, equipment limitations, places emphasis on herbicides	Fair	Low to medium
Cover crops, mulches, intercrop systems	Greater diversity, improved competitive ability, reduced selection pressure, possible allelopathy	Inconsistent impact on HR weeds, poor understanding of the system and lack of research information, lack of good cover crops, need to manage the cover crop/mulch	Fair to good	Low
Weed seedbank management	Reduced HR weed pressure, reduced selection pressure	Poor understanding about seed bank dynamics, need for aggressive tillage, emphasis on herbicides, high level of management skill required, need for novel equipment	Fair	Low to medium
Manipulation of nutrients	Improved crop competitive ability, efficient use of nutrients, lower nutrient costs, greater diversity	Poor research base, inconsistent results, potential for crop yield loss	Poor to fair	low
Flaming	Greater diversity, decreased selection pressure, relatively inexpensive equipment	Increased time required, increased costs, more fuel used, possible crop injury	Fair to good	low
Herbicide-resistant crops	Ability to use specific herbicides, no crop injury, control of existing specific herbicide resistances	Lack of diversity, increase selection pressure, concerns for non-target crops, possible limited weed spectrum	Fair to Excellent	Medium to high

Several innovations to improve weed management due to widespread herbicide resistance have come forward from Australia. One of these that has achieved considerable press is the Harrington Seed Destructor (Walsh et al., 2012). The goal is to better manage the weed seed bank by destroying weed seeds selectively during crop harvest. How widely adopted this technology is in Australia has not been determined but the equipment was developed for a small grain crop system and may not fit particularly well in Midwest crop production. Actually the concept is quite old as there were a number of grain harvesters that separated the weed seeds from the grain but they required that growers empty the weed seed reservoir; the weed seeds were typically fed to chickens and pigs – this was a time of more diverse agriculture.

Current and new genetically-engineered herbicide-resistant crops

Many companies that previously had active herbicide discovery programs have evolved to become "bioscience" companies and are attempting to improve weed management by introducing crops with genetically-engineered herbicide tolerance/resistance. There are a number of new genetically-engineered HR crops currently being developed and grower interest is high (Green and Owen, 2011). The benefits of the crops are documented in numerous review papers and the risks addressed as appropriate (Green, 2012; Green and Owen, 2011) (Table 2).

Currently available genetically-engineered herbicide-resistant crops

Obviously, the primary crops with genetically-engineered herbicide resistance (HR) have glyphosate resistance although glufosinate resistance in the major row crops is also a possible choice. The adoption of currently available HR crops, particularly those with glyphosate resistance has been for improved weed management (Table 2). Only 27% of the respondents to a recent questionnaire indicated that they had used crop cultivars resistant to herbicides other than glyphosate (Arbuckle Jr. and Lasley, 2013). The tactic was reported to be effective or very effective by 46% of the respondents.

Given the widespread evolution of resistance to glyphosate in many important weeds (e.g., waterhemp and Palmer amaranth), many question the utility and sustainability of crop systems based on glyphosate and current interest is on new HR crops. Glufosinate-resistant corn and soybean cultivars are available and in the south, growers have in many cases switched from glyphosate-resistant cultivars to glufosinate-resistant cultivars in an effort to manage Palmer amaranth problems. Unfortunately, many of the growers who are adopting glufosinate are also planning on using the same use practices that they used with glyphosate. To not learn from history is to repeat it; without appropriate stewardship and the inclusion of alternative tactics to supplement glufosinate, resistance in weeds will evolve quickly and thus put these growers in the same sinking boat that they now occupy with glyphosate.

New genetically-engineered herbicide-resistant crops

Crops with resistance to the auxin herbicides, specifically the dicamba-resistant soybean and the 2,4-D resistant soybean, are seen as the answer to the wide-spread glyphosate resistance issues. What need to be recognized is that these herbicides have different characteristics, limitations and liabilities that are different than what agriculture has become accustomed over the last decade plus. These auxin-resistant crops will provide good opportunities to manage some glyphosate-resistant weeds but expectations must be set appropriately and an understanding of the potential issues (e.g., off-target movement, application timing restrictions) addressed to maximize the benefits and minimize the risks. The commercial introduction of the auxin-resistant crops has been delayed due to an Environmental Impact Assessment that was imposed May 13, 2013. It is important to take advantage of the delayed but anticipated commercial launch of these technologies by learning more about how to best utilize the technologies and the herbicides that will be used; objectively review the published benefits and evaluate the risks.

Soybean cultivars with resistance to HPPD herbicides are also under development by Bayer Crop Science and Syngenta with collaborations with other companies. Bayer Crop Science in collaboration with MS Technologies has announced soybean cultivars with resistance to the HPPD inhibitor herbicide isoxaflutole (Balance) will be deregulated in time for planting in 2015. These soybean cultivars also have tolerance to glyphosate.

Syngenta and Bayer Crop Science submitted petitions to the USEPA and the Canadian Pest Management Regulatory Agency in the spring 2013 for approval of the HPPD inhibitor herbicide mesotrione (Callisto) use on MGI herbicide-tolerant soybean cultivars. The MGI herbicide-tolerant soybean cultivars also have tolerance to isoxaflutole and glufosinate (Liberty). Deregulation and commercial launch of the MGI herbicide-tolerant soybean cultivars is projected to be between 2015 and 2020.

A potential impediment to the utility of these HPPD inhibitor herbicide tolerant soybean cultivars in Iowa is the increasing presence of waterhemp with resistance to the HPPD-inhibitor herbicides (McMullan and Green, 2011). It is estimated that HPPD resistance in waterhemp may occur in 24% to 27% of Iowa soybean fields. These populations are likely to increase dramatically unless appropriate stewardship to protect these important herbicides is implemented soon.

Herbicide combinations and application rates

There has been considerable discussion about using more herbicide MOAs when creating a more diverse weed management program (probably better described as a more diverse herbicide management program) (Table 2). In the recently published Iowa Farm and Rural Life Poll, multiple modes of herbicide action (MOA) used each season were reported by 71% of the respondents and 60% of the respondents reported using multiple MOAs in each herbicide application. Generally these practices were reported in a favorable light (Arbuckle Jr. and Lasley, 2013).

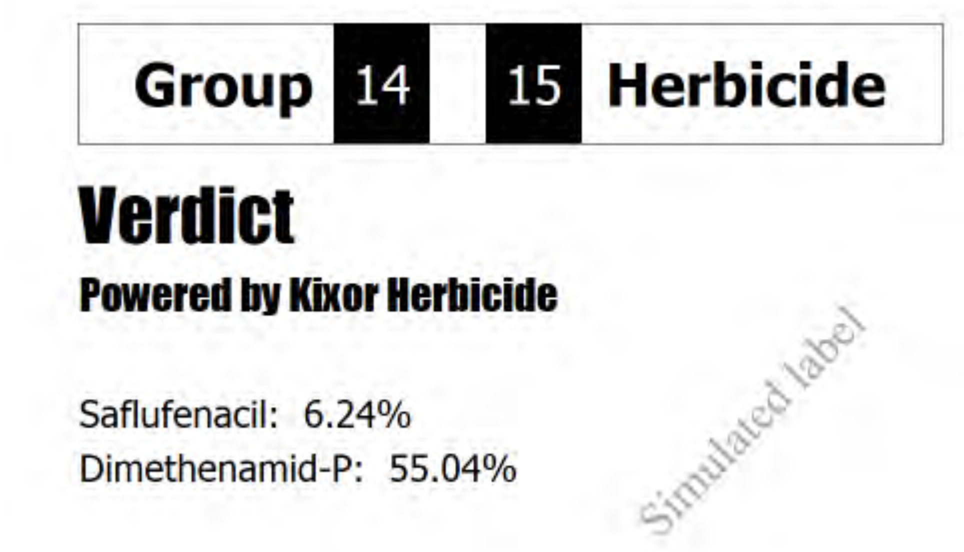

Figure 2. Example of a simulated herbicide label that includes herbicide group numbers designating the herbicide mode of action.

It is critical that the different MOAs are identified; simply using a different herbicide from a different company does not provide diversity. Thus, and important tool to use to make sure that the herbicides selected represent different MOAs is the herbicide group number. Herbicide group numbers are present on most herbicide labels and will facilitate the development of a multi-year herbicide management program that allows the greatest amount of herbicide MOA diversity (Figure 2).

There are two possible ways that diversity of herbicides can be achieved; rotation of herbicide MOAs or combining herbicide MOAs. Combining herbicide MOAs is more effective at managing weeds and mitigating herbicide resistance than rotating herbicides (Beckie and Reboud, 2009). The key to understanding the use of herbicide MOAs is recognizing the selection pressure an herbicide imparts on weed populations.

When combinations of herbicides are used, each application imparts multiple selection pressures instead of one source of selection that occurs when herbicide MOAs are rotated. Ideally, each herbicide application would include several herbicide MOAs and each herbicide would impart selection pressure that was the same as all other herbicides used in the mixture. However, the reality is herbicides used in mixtures will select weed populations differently which can eventually result in evolved resistance to the herbicide that imparts greater selection pressure (Diggle et al., 2003).

One key to using herbicide combinations is to make sure that the MOAs are actually effective. It does no good to include an herbicide if it is not active on the target weed. For example, there are a number of herbicide pre-mixtures that are advertised as being effective for managing herbicide resistance. However in many cases, the other herbicide MOA included in the mixture is a Group 2 product which generally is not effective on waterhemp, given the preexisting widespread Group 2 resistance.

Another key to consider is herbicide rate of application. While concerns for initial costs of herbicides often is the primary consideration, unless full rates of herbicides are used, the additional cost of supplemental herbicide applications and resultant control is likely to cost more than the initial investment required to apply the herbicide at the full rate appropriate for the field situation. Also, reduced rates are also likely to contribute to the evolution of herbicide-resistant weed biotypes sooner than when full rates are used (Gressel, 2011).

Conclusions

Unless better management tactics are quickly adopted, herbicide resistance will continue to increase at an increasing rate in Iowa, and given that no new herbicide sites of action have been discovered in the last 25 years, the future is not particularly bright for herbicidal weed management tactics. While new genetically engineered crops will provide different tactics for weed management, consider that the herbicides that will be available for use on these crops are not new products and waterhemp populations with evolved resistances to these herbicides already exist. It is imperative to develop more diverse approaches for weed management. If greater diversity is not part of the future for Iowa agriculture, weed management specifically will become increasingly costly and difficult. History has proven time and again that simple and convenient approaches inevitably fail.

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